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WI _____ 200808.09 _____

T _____ 411 _____

DRAFT NO. _____ 03 SARG _____

DATE _____ October 5, 2021 _____

WORKING GROUP
CHAIRMAN _____ Jeff Lundeen _____

SUBJECT
CATEGORY _____ Physical Properties _____

RELATED
METHODS _____ See "Additional Information" _____

CAUTION:

This Test Method may include safety precautions which are believed to be appropriate at the time of publication of the method. The intent of these is to alert the user of the method to safety issues related to such use. The user is responsible for determining that the safety precautions are complete and are appropriate to their use of the method, and for ensuring that suitable safety practices have not changed since publication of the method. This method may require the use, disposal, or both, of chemicals which may present serious health hazards to humans. Procedures for the handling of such substances are set forth on Material Safety Data Sheets which must be developed by all manufacturers and importers of potentially hazardous chemicals and maintained by all distributors of potentially hazardous chemicals. Prior to the use of this method, the user must determine whether any of the chemicals to be used or disposed of are potentially hazardous and, if so, must follow strictly the procedures specified by both the manufacturer, as well as local, state, and federal authorities for safe use and disposal of these chemicals.

Thickness (caliper) of paper, paperboard, and combined board

(Five-year review of Official Method T 411 om-15)

(Changes from Draft 1 incorporated)

1. Scope

1.1 This method describes the procedure for measuring single-sheet thickness and variations in single sheet thickness of paper, paperboard, and combined board. The term "combined board" encompasses both corrugated and solid fiberboard.

1.1.2 Selection of samples/specimens cut across the web (perpendicular to the machine direction) may be used to determine the cross machine caliper profile.

1.2 Because of the relatively high pressure 50 kPa (7.3 psi) used in this test method, it may not be suitable for measurement of tissue or other soft or low density materials, because the structure may collapse (decrease in thickness) at the prescribed pressure of 50 kPa. TAPPI T 580 "Thickness (caliper) of towel, tissue, napkin and facial products" should be used to measure these products. It uses a lower pressure of 2 kPa and a larger movable face with an area of 10 cm².

1.3 Another method for measuring the thickness of paper is TAPPI T 500 “Book Bulk and Bulking Number of Paper,” which describes a procedure for measuring the overall thickness of a stack of book paper under pressure of 250 kPa (35 psi).

1.4 An essentially identical method is described in ASTM D 645-96.

1.5 TAPPI T 551 “Thickness of Paper and Paperboard (Soft Platen Method)” describes a method for measuring the effective thickness of paper and board products utilizing soft rubber platens. This method always yields smaller values than TAPPI T 411.

2. Summary

This method involves measuring the thickness of a single sheet of paper, paperboard, or combined board by the use of an automatically operated micrometer when a specified static load is applied for a minimum specified time¹.

3. Significance

Thickness is an important property of paper, paperboard, or combined board, and variations in thickness are also important especially for papers and paperboards used for mechanical purposes. This test is useful for research work, routine control, design of end-use products, and for acceptance testing for conformance to specifications. Thickness is one of the important characteristics that affects flexural stiffness.

4. Definition

Thickness or caliper of paper, paperboard, and combined board as measured by this method is defined as the perpendicular distance between the two principal surfaces of the paper or paperboard under prescribed conditions, as measured between hard metal platens. This should not be confused with apparent thickness as determined by other means, e.g., between soft platens or calculated from bending stiffness.

5. Apparatus¹

5.1 *Automatically-operated micrometer*², a dead-weight type instrument, provided with:

5.1.1 A flat ground circular movable face (hereafter called the pressure foot), having an area of $200 \pm 5 \text{ mm}^2$ (equivalent to about 0.31 in.^2) and corresponding to a diameter of $16 \pm 0.15 \text{ mm}$ (0.63 in.).

¹Names of suppliers of testing equipment and materials for this method may be found on the Test Equipment Suppliers list, available as part of the CD or printed set of Standards, or on the TAPPI website general Standards page.

²Manually operated micrometers are not allowed in this method due to nonconformity.

5.1.2 A flat ground circular fixed face (hereafter called the anvil) of such size that it is in contact with the whole area of the pressure foot in the zero position.

5.1.3 Surfaces of the pressure foot and anvil shall be parallel to within 0.001 mm (0.00004 in.). The pressure foot movement shall be on an axis perpendicular to the anvil. The minimum distance between the anvil and the pressure foot in the “up” or raised position shall be 0.75 mm (0.030 in.) for paper or 12 mm (0.500 in.) for a combined board.

5.1.4 Pressure foot lowering speed of 1.0 ± 0.3 mm (0.04 in.)/s (see also Additional information). There may be differences in the results as compared to the previous rate of lowering. In manually operated caliper instruments, the pressure foot must be lowered slowly and not be allowed to “drop” onto the specimen surface.

NOTE 1: This may be checked by measuring the eccentricity and speed of rotation of the cam operating the pressure foot.

5.1.5 Pressure foot, when lowered, exerting steady pressure of the anvil on the specimen of 50 ± 2 kPa (approximately 7.3 psi) for 2 ± 1 s.

5.1.5.1 The frame of the micrometer shall be of such rigidity that a load of 1.5 kg (3 lb) applied to the dial housing, out of contact with either the weight or the pressure foot spindle, will produce a deflection of the frame not greater than 0.0025 mm (0.0001 in.), as indicated by the micrometer readout system.

5.1.6 *Readings* (5.1.6.1 or 5.1.6.2 as applicable).

5.1.6.1 Dial, graduated to 0.002 mm (0.00008 in.) or less, readable to at least 0.001 mm (0.00004 in.), or 1% of paper thickness, whichever is larger. If the large indicating hand of the dial is required to revolve more than once to cover the capacity of the gauge, equip the dial with a revolution counter to indicate the number of complete revolutions of the indicating hand.

5.1.6.2 Digital display with indication to at least 0.001 mm (0.00004 in.), or 1% of paper thickness, whichever is larger.

5.1.7 Capability of repeating readings to within 0.001 mm (0.00004 in.) at zero settings or on a steel gage block.

5.1.8 Accuracy within 0.001 mm (0.00004 in.) or 1% of paper thickness, whichever is larger.

6. Calibration

6.1 *Accuracy of dial indications.* Use standard steel gage whose thickness is known to within 0.0005 mm (0.00002 in.); check the accuracy of the dial reading over the required range. Prepare a calibration curve or table if necessary.

6.1.1 Digital read out instruments capable of greater accuracy than dial indicator instruments may require standard steel gages accurate to within 0.00025 mm (0.00001 in.) or better if this greater accuracy is required.

NOTE 2: In the use of steel gage, a nondeformable material, it must be remembered that the value corresponding to the thickest portion of the gage, rather than the average thickness, should be used in calibration of the micrometer.

6.2 *Parallelism of the faces.* Use a uniform diameter wire of any size up to half the operational opening of the faces, e.g., 0.05 mm (0.020 in.) diameter. Place the wire alternately on the left side, right side, front side, and back side approximately 3 mm (0.125 in.) from each respective edge of the foot and note the readings. Adjust anvil so that all readings are within 0.001 mm (0.00004 in.) of one another. A thickness gauge may also be used if a uniform wire is not available.

6.3 *Pressure between the faces.* Within the normal thickness measuring range measure the pressure exerted by the deadweight mechanism, and pressure foot on the anvil shall be 50 ± 2 kPa. Any suitable means to verify may be used.

7. Sampling

Obtain a sample in accordance with TAPPI T 400 "Sampling and Accepting a Single Lot of Paper, Paperboard, Containerboard, or Related Product."

8. Test specimens

From each test unit of the sample, cut ten specimens, each specimen consisting of one ply of paper (i.e., a single sheet) at least 40 mm (1.57 in.) (preferably 80 mm for combined board) in its shortest dimension and at least 120 mm (approximately 4.75 in.) in its longest dimension. For thickness profile measurements, cut the specimen strips so that the longer dimension is across the machine direction. (Determine the machine direction in accordance with TAPPI T 409 "Machine Direction of Paper and Paperboard.")

9. Conditioning

Precondition, condition, and test all specimens in atmospheres controlled in accordance with TAPPI T 402 "Standard Conditioning and Testing Atmospheres for Paper, Board, Pulp Handsheets, and Related Products."

10. Procedure

10.1 Before using the micrometer, make sure the pressure foot and anvil surfaces are clean, the calibration of the instrument has been verified and a calibration curve has been prepared, if necessary, and the instrument is mounted on a solid level surface free from noticeable vibration. Place the specimen on the anvil in such a position that all points on the peripheries of the contact surfaces are at least 6 mm (approximately 0.25 in.), or 12 mm for combined board, from the edges of the specimen. To determine the cross-machine caliper profile, measure the thickness of each specimen at five non-overlapping regular intervals in a line at right angles to the machine direction of the paper. If

only the lot or test unit average is required, i.e., variations of thickness within a sheet are of no interest, then only two readings per specimen need be made.

10.2 Take each reading near the end of the dwell time (2 ± 1 s). If necessary, apply the calibration corrections to the readings.

NOTE 3: If the thickness of noticeably compressible papers is being measured, it is particularly important that the rate of fall of the pressure foot and the dwell time be within the specified limits. (See 5.1.4 and 5.1.5.)

11. Report

For each test unit of the sample report the overall average (50 or 20 readings) in millimeters (or inches) to the nearest 0.001 mm (0.00004 in.). Also, when specified, report the minimum and maximum thickness obtained for each specimen to the nearest 0.001 mm (0.00004 in.). For coarse paperboards and combined boards, report average to 0.01 mm (0.0004 in.).

12. Precision

12.1 Repeatability (within a laboratory) = 1.25% (based on 50 readings).

12.2 Reproducibility (between laboratories) = 5.50% in accordance with the definitions of these terms in TAPPI T 1200 "Interlaboratory evaluation of test methods to determine TAPPI repeatability and reproducibility."

12.3 The above precision was calculated from data taken from 24 reports of the CTS-TAPPI Collaborative Reference Program for paper. The user of these precision data is advised that it is based on actual mill testing, laboratory testing, or both. There is no knowledge of the exact degree to which personnel skills or equipment were optimized during its generation. The precision quoted provides an estimate of typical variation in test results which may be encountered when this method is routinely used by two or more parties.

13. Additional information

13.1 Effective date of issue: To be assigned.

13.2 For a method in which the pressure foot is lowered at a speed slower in comparison with the speed in this method, test results have been reported to be as much as 3% higher, depending on the type of paper.

13.3 Related methods: AS 1301.426s "Thickness of Single Sheets of Paper, Paperboard and Corrugated Fiberboard," Technical Association of the Australian and New Zealand Pulp and Paper Industry, Parkville, Australia; BS 3983; PAPTAC D4 "Thickness and Apparent Density of Paper and Paperboard," Pulp and Paper Technical Association of Canada, Montreal, Canada.

13.4 *ISO procedure.* ISO 3034 “Corrugated fiberboard – Determination of Thickness.” The most recent draft of the International Standard (ISO 534) lists the preferred pressure exerted by the foot to be 100 kPa. The results may not be the same.

13.5 Revisions in the 2010 edition of this standard include deletion of reference to ISO 534 as an alternative method (including the deletion of former Note 2), correction of measurements in 5.1.3, and deletion of a reference to alternative pressure in the Report. Revisions in the 2015 edition included clarification of section 1.1.2, information about manually operated instruments in 5.1.4, and updates to the related methods in Additional Information.

14. Keywords

Micrometers, Thickness, Combined boards, Paper, Paperboard, Corrugated boards

Your comments and suggestions on this procedure are earnestly requested and should be sent to the TAPPI Standards Department. ■